Cost of retrieving inventory records

A request was made on March 3, 1998 to LBNL for its tritium inventory records. LBNL responded that it would provide the records if it were paid $30,000 - $40,000. The parties interested in the radioactivity emitted by LBNL cannot afford this cost, and the records have not been provided. These records should be provided free-of-charge because of the following two reasons.

1) The amount of radioactivity in the tritium stock is sufficiently large to be fatal to humans. Dangerous materials should be kept track of. In the case of tritium, the danger disappears after several half lives, which is after about 100 years. LBNL should have the inventory records of the whole tritium project readily available in case of accident or unauthorized disposition of the tritium. If LBNL has neglected to create or to maintain comprehensive inventory records, it should begin to do so now. The completeness of any present records should be determined by a non-DOE agent. A copy of the present records, the completeness report, and future records should be made available to the public.

2) A cost of $40,000 is small for LBNL and should be absorbed by LBNL. A comparison with only a small part of the cost of LBNL public relations is relevant. The cost of the meetings with the neighborhood groups surrounding LBNL is given very approximately in the following table

Item	Quantity
Annual budget of LBNL	$350M
Number of LBNL employees	3000
Cost of one employee hour	$50
Approximate number of government paid people at April 25 meeting	12
Length of April 25 meeting	3 hours
Cost of April 25 meeting	$2000
Cost of possible 7 meetings	$14,000

The cost of preparing for the neighborhood meetings probably equals the cost of the meetings themselves. Adding in the costs of meetings that LBNL has with the Berkeley city government. school boards, and possibly other organizations, the total cost easily equals $40,000. LBNL has not asked for compensation for these meetings because it can afford them. It can also afford any costs of producing inventory records.

In summary, LBNL should possess comprehensive inventory records of its tritium in the same way that it possesses and maintains records of its other radioactive sources. A copy of these records should be available to the public.

Respectfully submitted,

Eric Arens
Campus Parnassus Neighborhood Group, President
May 23, 2000

The ominous stack

The following questions are about the emissions from the National Tritium Labeling Facility (NTLF) through the stack.

1) Why is there a discharge of tritium into the environment? Why is it not all recaptured and recycled? (Tritium must be carefully produced at the Savannah River plant and is probably expensive to transport to LBNL. Recycling within LBNL might have cost advantages.) This discharge is 2% of the tritium that passes through LBNL. (This percentage is stated in the Quality Assurance Project Plan for Tritium Sampling, but the statement is ambiguous and can be interpreted to mean a lesser percentage.)

2) Is the tritium discharge sufficiently large to
   a) require venting outside the source building (instead of inside)?
   b) require venting far removed from the source building (instead of on the roof)?
   c) require venting on the downwind side of the LBNL land (instead of on the upwind side of the building where the emissions originate.)

3) Can an unplanned large discharge occur due to accident, unintentional human action, or intentional human action? How large is the reservoir of gas in the building?

4) The Quality Assurance Project Plan for Tritium Sampling does no. include monitoring the effluent from the stack. Uninterrupted monitoring and the creation of a continuous record are commonly performed today where a danger exists. Such a record would be extremely useful to anyone calculating the danger arising from almost any tritium release scenario.

5) When were the NTLF buildings constructed? Was the vent pipe constructed then? Are the architectural and engineering specifications for the building still in existence?

6) The Quality Assurance Project Plan for Tritium Sampling includes a procedure that the LBNL Radiation Protection Group be notified whenever LBNL personnel take samples in the vicinity of the stack. Is this area dangerous? If not, this procedure is a waste of taxpayers' money.

In summary, the NTLF has a tritium discharge stack that is placed in a location that minimizes the dispersal of the effluent onto LBNL personnel. The effluent goes elsewhere. People in this effluent dispersal field are asking about the effects of the tritium, both from planned and unplanned actions at the NTLF.

Respectfully submitted,

Eric Arens
Campus Parnassus Neighborhood Group, President
May 23, 2000

Amounts of tritium and radiation discharged from the LBNL NTLF with a view toward making these amounts more understandable to the general public

Eric Arens
May 29, 2000

Radioactivity

Some atoms disintegrate spontaneously, and the parts that fly out can hit molecules and break them apart. These atoms are radioactive. Radioactivity is measured by the number of disintegrations per second, the energy of the emitted fragments, and the effectiveness of the fragments to cause damage.

One disintegration per second is a Becquerel (Bq), and 3.7 x 10^{10} Bq = 1 Curie (Ci). Half of the tritium in a sample will disintegrate in 12.36 years (y). Each tritium disintegration produces an electron, and the average energy of the electrons is 5.7 thousand electron volts (keV). The effectiveness of the fragments to cause damage is given by the quality factor, F_Q , which has been determined to be in the range of 2 to 5 by biological experiment. The value of 2 will be used here.

Quantity of tritium

The stock of tritium that is brought into the NTLF every year produces about 10,000 Ci of radiation. The number of tritium atoms in this stock is 2 x 10^{23} atoms as shown in the Appendix. If these atoms are all in water molecules (HTO) that each have one tritium atom, the volume of water is about 7 cubic centimeters or 1/3 cubic inch.

The following two calculations, one for ingestion and one for breathing tritiated water, are shown to

- show the amount of radiation in the annual LBNL stock in terms of its effect on people
- show the methods used in making radiation dose calculations.

The calculations are performed by mainly using multiplication and division, with which most people are familiar.

Dose of radiation by ingestion and the effect on a person

If a person of weight $W = 150\ \text{lb} \approx 70\ \text{kg}$ drank all this tritiated water, he would flush most of it out in 10 days by natural water replacement and receive a radiation dose of

$$n_{rem} = n_{rad} \times F_Q$$

$$= -\int_0^{10days} = dN/dt \quad dt \times \mathring{A}_{ave} \times F_Q \frac{1}{100 erg/g} \times \frac{1}{W}$$

$$\approx -\frac{dN}{dt} \times E_{ave} \times F_Q \times t \times \frac{1}{100 erg/g} \times \frac{1}{W}$$

$$\approx \frac{3.7 \times 10^{14} \ s^{-1} \times 5.69 \ \text{keV}}{6.25 \times 10^{-7} \ Mev \ g^{-1}} \times 8.64 \times 10^{5} s \times \frac{2}{70 \, kg} rem$$

$$= 832{,}000 \ rem$$

For comparison, the following approximate exposures are given.

- A person receives ≈ 100 mrem (100/1000 rem) in a year from natural and medical sources.
- An acute (quick) dose of 100 rem produces no noticeable illness
- An acute dose of 500 rem will kill approximately half the people that were irradiated

Dose of radiation by breathing

If a person were in a room in which the 10,000 Ci of HTO had been evaporated, he would receive a number of rem as calculated below.

Volume of 1 breath = 1 pint.
Breathing rate = 12 breaths per minute.
Room air replacement time (typical) = 1 hour.
Volume of air breathed in = 1 pint/breath $\times$ 12 breaths/min $\times$ 60 min/hr $\times$ 1 hr = 1800 pints = 11 cubic feet.
Volume of the room = 15 ft $\times$ 15 ft $\times$ 8 ft = 1800 cubic feet.
The fraction of tritium breathed in = 11 cu ft / 1800 cu ft = 0.006.
Radiation dose received = 0.006 $\times$ 832,000 rem = 5100 rem.

Dose of radiation to people in neighborhoods close to the NTLF stack

The closest houses to the NTLF stack are on Olympus Avenue and Campus Drive, at a distance of 400 meters. The radiation dose to the people in these houses is calculated here.
If the plume from the stack has a cone angle of 10 degrees and 2% of the 10,000 Ci of the annual incoming tritium stock passed through the stack into a 5 km/hr wind, the density of tritium at 400 meters would be

$$D = \frac{N_0 \times 2\%}{1\,y \times 3847\,m^2 \times 5\,km/hr}$$

$$= \frac{2.08 \times 10^{23}\,atoms \times 0.02}{3.16 \times 10^7\,s \times 3847\,m^2 \times 1.39\,m/s}$$

$$= 2.4 \times 10^{10}\ atoms/m^3$$

Using the calculation methods in the Appendix, the radioactivity of this air is

$$\frac{dD}{dt} = \frac{2.4 \times 10^{10}\ atoms/m^3}{5.63 \times 10^8\,s} \times \frac{1\,pCi}{3.7 \times 10^{10} \times 10^{-12}\ dis/s} = 1150\ pCi/m^3\,.$$

A person taking 0.5 1iter breaths 12 times per minute breathes a volume rate of

$$\mathrm{R} = 0.1\,l/\mathrm{s} = 1.0 \times 10^{-4}\ m^3/\mathrm{s}\,.$$

If he absorbs 90% of the water and flushes it out in 10 days, the steady state number of tritium disintegrations per second in the person is is the number of absorbed HTO molecules per second minus the number of 10 day old ($8.64 \times 10^5\,s$) nondisintegrated HTO molecules flushed out per second.

$$N_{dis} = 2.4 \times 10^{10}\ atoms/m^3 \times 1.0 \times 10^{-4}\,m^3 s^{-1} \times 0.9\left[1 - e^{-8.64\times10^5 s/5.63\times10^8 s}\right]$$
$$= 2.2 \times 10^6\,[1 - 0.99847\,]$$
$$= 3.3 \times 10^3\,Bq.$$

The dose of radiation the person would receive by breathing for a year is

$$n_{rem} = N_{dis} \times E_{ave} \times F_Q \times t \times \frac{1}{100\,erg/g} \times \frac{1}{W}$$
$$= 3.3 \times 10^3\ s^{-1} \times 5.69\ kev \times 2 \times 3.16 \times 10^7\ s/y \times \frac{1}{6.25 \times 10^7\ MeV/g} \times \frac{1}{70\ kg}$$
$$= 0.27\ mrem/y.$$

Water intake by absorption through the skin roughly equals the absorption through the lungs. A person at a distance of 400 meters and constantly in the plume for a year would receive 0.54 mrem of radiation.

Some of the assumptions in this calculation are probably wrong. Some make the radiation dose too high, and others make the dose too low. Some reasons that the calculated dose might be too high are

1) The plume shifts as the wind shifts.

2) Almost nobody is home all the time.
3) The wind speed might be greater than 5 km/hr.

Some of reasons that the calculated dose might be too low are

1) The cone angle is probably less than 10 degrees in the vertical direction.
2) The operational release of tritium could be higher than 2%, as has been reported.
3) There have been occasional accidental large releases, which are in addition to the 2%
4) The quality factor F_Q might be higher, such as 5 instead of 2.
5) The wind speed might be less than 5 km/hr.

This calculation applies to houses at the ends of Olympus Avenue and Campus Drive. People in houses further away receive less radiation; people at the Lawrence Hall of Science receive approximately 10 times more radiation because the distance of the stack to the LHS is 1/3 of the distance to the closest neighborhood houses.

Conclusions-reached from the above plume calculation

The calculated dose of 0.54 mrem/y is about equal to 1% of the yearly dose a person receives from all natural and medical sources. The Health Physics Society (EPA Radiation Information book) states that 1 to 5 mrem/y is generally an acceptable exposure from a man made source. The ease of avoiding this exposure and the benefit of the exposure should also be considered. Since the calculated dose from the NTLF stack is roughly equal to the maximum HPS acceptable dose the situation is a close call, and the underlying assumptions in the calculation should be reviewed. At least the reasons why the calculated dose might be too low or be too high should be investigated.

This calculation explains why LBNL built the stack far away from LBNL buildings and on the downwind side of the LBNL land in the prevailing winds. For example, if the stack were 15 meters (about 50 feet) away on the upwind side of a building, the dose to a 24 hour a day workaholic inside would be 1 rem/y.

Radioactivity of groundwater

Some of the groundwater measurements around the NTLF stack have shown the tritium radioactivity to be around 50,000 picoCurie per liter (pCi/l). The following calculation converts this radioactivity to rem, which is a quantity that is used to measure radiation effects on people.

If a person contained 50,000 pCi/l of tritium, he would receive the following amount of radiation in a year. A person is composed mainly of water, and he could achieve this concentration by solely drinking the groundwater and eating food grown in it or by breathing the plume air and possibly absorbing an amount of tritium that would produce the same concentration as the absorption by the ground produces. The absorption by a person and by the ground might be vastly different, but the following result can be used in any case to see what 50,000 pCi/l is in rad equivalent man (rem).

$$N_{rem} = 50{,}000\, pCi/l \times E_{ave} \times F_Q \times t \ \times \frac{1\, rad}{100\, erg/g}$$

$$= 5\times10^4 \times 10^{-12}\,\frac{Ci}{l} \times 3.7 10^{10}\,\frac{dis}{s\ Ci} \times \frac{1l}{1000\, g} \times 5.69\times10^3\,\frac{ev}{dis} \times 2\times3.16\times10^7\,\frac{s}{y} \times \frac{1\ rad}{6.25\times10^{13} 3\, eV/g}$$

$$= 0.0106\ rem/y$$

$$= 10.6\ mrem/y.$$

The groundwater radioactivity might or might not have much relevance to the radioactivity in a person situated in the plume from the stack. For example, reasons that the dose calculated above might be too high include

1) the distance of people from the stack is greater than the distance of the groundwater samples from the stack

2) the groundwater might be mainly produced by tritium entrained in rain, and people do not generally stand in the rain

3) the flushing time through a person might be higher than the flushing time through the ground.

Reasons that the above dose might be too low is

1) a person's lungs pump a lot of air past the absorbing surface

2) The flushing time through a person might be lower than the flushing time through the ground.

This calculation using the measured groundwater concentrations of tritium might have little to do with the tritium in a person. However, since the radioactive dose calculated from the emission from the stack is in the same ball park as the dose calculated in groundwater, there might be a correlation. If there is a close correlation, it could be used as a monitoring tool.

Appendix Amount of tritium in the incoming NTLF stock

N_0 is the initial number of tritium atoms in a shipment of tritium at the time of delivery to LBNL.

N is the number of tritium atoms in the shipment at any time. N decreases with time as some of the atoms disintegrate.

T is the time it takes for enough tritium atoms to disintegrate so only 1/*e* (36.8%) of the initial tritium atoms remain intact.

t is time.

T is found from the half life,

$$\frac{N}{N_0} = \frac{1}{2} = e^{-0.693} = e^{-12.35 \; y/T}$$

$$T = 17.82\, y = 5.63\times10^{8}\, s$$

The number of tritium atoms that have not distintegrated is

$$N = N_0\, e^{-t/17.82y} = N_0 e^{-t/5.63\times10^{8} s}$$

The initial disintegration rate of the incoming stock is 10,000 Ci,

$$\left.\frac{dN}{dt}\right|_{t=0} = \frac{N_0}{5.63\times10^{8}\, s} = -10^{4}\times3.7\times10^{10}\, s^{-1} = -3.7\times10^{14}\, s^{-1}\,.$$

Therefor the initial number of tritium atoms is

$$N_0 = 2.08\times10^{23}\, atoms.$$

As the stock disintegrates, the number of tritium atoms decreases as

$$N = 2.08\times10^{23} e^{-t/5.63\times10^{8} s}$$

The disintegration rate is

$$\frac{dN}{dt} = 3.7\times10^{14}\, e^{-t/5.63\times10^{8}\, s}\,.$$

If the incoming stock were in singly tritiated water (HTO), the density of the water would be

$$D_{HTO} = \frac{20}{18}\frac{g}{\mathrm{cm}^3} = \frac{20}{18}\frac{g}{\mathrm{cm}^3}\frac{1}{20g / N_A} = 3.34 \times 10^{22}\ atoms/\mathrm{cm}^3$$

where Avogadro's number is

$$N_A = 6.02 \times 10^{23} molecules.$$

and the gram molecular weights of H_2O and HTO are 18 and 20 respectively.

The volume of the water would be

$$V = \frac{2.08 \times 10^{23} atoms}{3.34 \times 10^{22} atoms/\mathrm{cm}^3} = 6.22\,\mathrm{cm}^3 \approx 1/3\, cubic\ inch.$$